
PUBLIC HEALTH RESEARCH

Safety Culture in Handling Radioactive Materials for Radiation Practitioners: A Review

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ABSTRACT

Safety culture refers to how safety is addressed and communicated in the workplace. It encompasses the attitudes, beliefs, perceptions, and values of all employees in an organization about safety. A good safety culture can be promoted by management through a commitment to safety, realistic practices for handling hazards, continuous organizational learning and concern for hazards shared across the workforce. The objective of this paper is to reviews the safety culture in handling radioactive sources. The radioactive substances used should comply with the following characteristics where radiotoxicity must be as low as possible, short-living isotopes are preferred to long-living ones and the amounts used must be kept to a minimum. Therefore, the As Low As Reasonably Achievable (ALARA) principle was applied that based on the minimization of radiation doses and limiting the release of radioactive materials into the environment by employing all reasonable methods. Besides that, the ALARA principle is an integral part of all activities that involve the use of radiation or radioactive materials and can help prevent unnecessary exposure as well as overexposure. The three major ALARA principles to assist with maintaining doses are time, distance and shielding. It takes a whole team effort to successfully implement the ALARA in safety culture while doing routine elements of working in handling radioactive materials.

Keywords ALARA - Handling - Radioactive sources - Review - Safety culture.

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INTRODUCTION

Most radiation practitioners were always involved with radioactive sources while working. Safety is one of the important issues that debate nowadays. Many believed that practicing ALARA in the radiation field especially medical imaging instruments can help to reduce the radiation risks exposed to the patients and society. Since handling radioactive material need professional to take care of it, it will also open many job opportunities to nuclear medicine and radiology students to further their career. Any nuclear agencies also play a vital role to ensure the safety of both patients and the radiologist by organizing talks, conferences regarding the importance of ALARA.

Promoting of Safety Culture

Many organizations tend to focus on occupational health and safety (OHS) promotion strategies on displaying the number of days since the last lost-time injury but fail to capitalize on the promotional opportunity that presents.¹ Next, the promotion of occupational safety and health (OHS) not only will stay in a rigid position and must beyond the expectations not only focus on preventing problems but also can highlight innovation and achievement.²

The organizations that related and work together on OHS need to implement physical improvements and management systems where the safety culture can be promoted through this improvement. The campaign that promoting safety culture should be rewarded and can winning contracts because the safety systems and culture are in place and through campaigning can improve the investigation and documentation of incidents, better risk assessments and job safety procedures.³ Other than special campaigning, there are many strategies to promote safety cultures to the employee for examples mission statements, slogans and logos, through published materials in the library, statistics and newsletters or through media such as posters, displays, audiovisual, e-mail and internet and lastly through seminars and training either in short talks or group meetings.⁴

Next, the promotional activities must know customer focus and must client drove, line management and shop floor employees have different needs and there are different ways to approach because of that it is important to know who the target is and what the needs. The different people have different levels and different hierarchical levels of an organization have different needs. The ways of the promotional activities should be different especially the new ideas from the old one and types of activities. The level or types of people can be classified into four groups which are early adopters, early majority, late majority, and non-adopters.⁵

Then, annual performance appraisals which result in rewards such as promotions, prizes or bonuses will motivate managers to work harder

and in safety culture. The specific health and safety performance indicators must be included in the manager's position and engage senior management to frequently promote and reinforce the expectations.⁶ The implementing organization has to be confident that its work meets established criteria, the regulator has to be confident in the work being carried out by the implementer and the public has to be confident that both are doing their job properly and thus ensuring that waste can be disposed of safely.⁷

Obviously, without the confidence and acceptance of decision-makers, policy-makers and, most importantly, the general public, the implementation of waste disposal and how to handling the radioactive material in safety culture programs will continue to flounder. The government is therefore expected to clearly define the role of the implementing organization by national policy. The government is also responsible for setting up a system for siting, promotion of public understanding of waste policy and proposals for the development of local economies and infrastructure. It may be difficult to achieve sufficient public understanding and acceptance through the efforts of the implementing organization alone.⁸

Besides that, to promote safety culture organization, company or government can recruited staff including trained public relations personnel that intended to act as an interface with local people, also the establishment of local visitor's centers together with handling in radioactive material and sharing the product of radioactive materials with the locals so that all the locals can get knowledge.⁹ In addition, periodically review training programs and working methods of the management system and staff can keep the promotional of safety culture works among the staff and organization.¹⁰

Important of Safety Culture

A necessary characteristic to reach safe nuclear installations is meant by a safety culture and it must be possible to assess its status to improve and maintain it at optimal levels.¹¹ When an organization is willing and able to work according to the demands of its ask and when people understand the changing vulnerabilities of their work environment due of that safety culture can emerge in the working environment.¹²⁻¹⁴

In the nuclear industry especially when handling radioactive material, the safety culture of any organization should be centered on safety. The safety culture is important to show human awareness on the capability of nuclear power plants or radioactive material to bring destruction to the community and much attention is needed to obtain the benefits from the applications of radioactive material.¹⁵ Safety is more specifically described as the protection of humans and the environment, now and in the future, against the dangers arising from

ionizing radiation in nuclear research and regulations.¹⁶

All the workers at the nuclear power or radioactive material handling should be sent for training for examples at General Employee Training (GET) and Plant Access Training (PAT), due of that employer can obtain basic familiarity of the site layout, function of major departments, site policies, site quality program, site emergency planning, radiation areas at the site, basic radiation protection and basic industrial safety.¹⁷

The safety culture should be applied especially in nuclear power as nuclear technology and all its applications included power generation can continue to be developed in future decades if appropriate levels of these three aspects are preserved and if they are approached in a more integrated and holistic manner.¹⁸ The population and environment should be protected from the radiation and other hazards caused by the operation of nuclear power plants and nuclear facilities at all stages of life cycle, storage, transportation and radioactive materials utilization including spent nuclear fuel and radioactive waste because there is a limit radiation exposure to personnel, population and environment that already stated in the rules of safety culture.¹⁹

The plants and animal species can have exposed to radiation if managements of Radiation safety and radioactive waste (RAW) fail to protect the environment from being contaminated. Exposure can arise at present and can also occur in the future, and its reading can be from low to high depending on the nature of the RAW and the circumstances of exposure.²⁰ The safety culture can keep the radionuclides within the containment boundary by chemical or physical fixation within the waste matrix and by physical containing barriers, and to provide shielding for any penetrating radiation emitted from the radionuclides within the waste, so that the radiation cannot be exposed to the environment.²¹

There are several important generic concepts for near-surface disposal that can be described as follows. Firstly, a covered trench is the oldest and simplest of the disposal concepts and it consists of placing waste into excavated trenches and covering the filled trenches with soil. Secondly, a closed vault consists of a concrete vault into which the packaged and/or treated waste is placed. The voids may be backfilled, and the structure is enclosed with concrete slabs, which may be sealed by, for example, asphalt. Next, is a domed vault where in this design the infiltration is controlled by placing waste in a dry permeable layer and covering the waste with an impermeable concrete roof that is subsequently protected by an earthen cap and lastly, is open vault wherein this concept, a low permeability cap is placed over the filled vault without emplacement of a concrete lab where the waste is however pretreated to minimize the voids.²²

Safety Culture consists of the overall attitudes, (implicit) assumptions, beliefs, perceptions and habits within an organization that is relevant for OHS. However, the conceptualization of Safety Culture has changed substantially over time to encompass the current understanding of OHS and the characteristics of the work environment.²³ As the growing importance of Psychosocial risk factors, these must be included as part of the policies, procedures and activities of an organization and are also reflected in the Safety Culture of an organization.²⁴

Safety culture concept

The safety culture in every organization is reflected in human awareness and acknowledgment of the significant destructive capability in the industry.²⁵ From the previous study, there is some suggestion of safety culture features that perform high-risk activities in complex environments and yet maintain excellent safety performance and operational efficiency suitable in safety performance measurement.²⁶⁻³¹

Six features correlated with safety performance including a top-level commitment to safety, organizational learning, organizational flexibility, awareness, just culture and emergency preparedness.²⁵ The first feature is a top-level commitment to safety, this is the priority and most important attribute. The top-level commitment to safety must be contributing to all workers which managers demonstrate their commitment in their attitudes to safety, and the allocation of resources, including the time spent on efforts to improve safety. This how it recognizes human performance concerns, permeating the organization with a sense of significance on how human performance influences safety and on how the organization can provide resources for safer work.

Next, organizational learning related to the identification of better ways in carrying business based on experience helps to solve the new issue that will appear. Organizations that fail to learn from small events or weak signals resisting beyond a reasonable level, without changing the way they are doing things, are probably at greater risk of major accidents.³² On the other hand, organizational flexibility represents the ability of the system to restructure itself using existing resources in response to external changes.²⁵

Awareness is focused on how a system facilitates data-gathering and understanding to provide management acknowledge or know about what going on in work. It is related to the quality of human performance in the organization and the extent that it can be a problem.²⁵

For just culture, it is a barrier that should be concern about between acceptable and unacceptable actions (Figure 1). It a dominant safety culture due to its role in the reporting of weak signals up through

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the organization. Without a just culture, the willingness of the workers to report problems will be much weakened, thereby limiting the ability of the organization to learn about weaknesses in its current defenses.³²

Lastly, emergency preparedness is usually applied at all levels of the organization. However,

there must be up-to-date realistic response plans in place to cover the major types of safety concerns. This helps them to get ahead problem and prepare how to handle it as preparedness itself means being ahead of the human problem and its effect.³

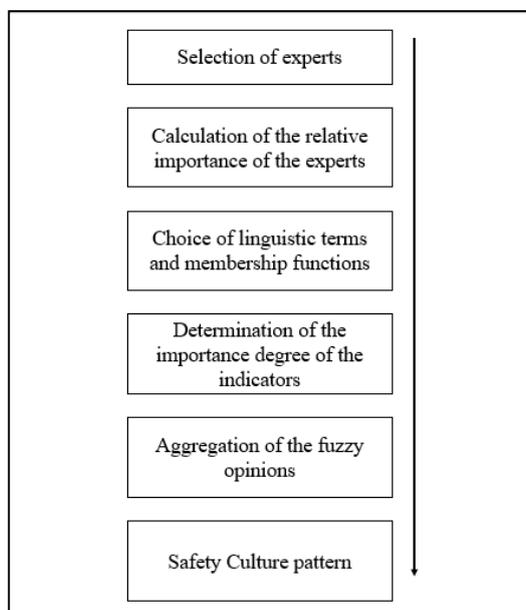


Figure 1 Schematic diagram to determine safety culture pattern

Safety Culture in Handling High Dose Radioactive Material

Safety Culture includes the overall attitudes, assumptions, beliefs, perceptions and habits within an organization that is relevant for OHS. However, the conceptualization of Safety Culture has changed substantially over time to encompass the current understanding of OHS and the characteristics of the work environment.³⁴⁻³⁵ The safety culture of an organization needs to include policies, procedures and activities of the organization.³⁶⁻³⁷ Other than that, there are three types of leading indicators are identified including compliance, improving performance and learning organization. Every type of indicator is depending on the organization's suitability of safety culture.

Petrochemical plants and nuclear power plants are an organization that develops safety culture. This is very important to reduce human error and any accident.³⁸ In addition, several studies state that safety emerges when an organization is willing and able to work according to the demands of its asks and when people understand the weaknesses of their work environment.^{9,15-39} From 2006 to 2008, approximately about 0.032% of Gross Domestic Product (GDP) after Malaysia's involvement in nuclear technology based on the development of Nuclear agency.⁴⁰ The energy demand makes the nuclear power plant needed to fulfill it as the economic transformation plan.⁴¹ However, there are

limitations on safety culture practice that has been conducted in nuclear and radiation in the context of Eastern countries like Malaysia compared to the petrochemical sector.

All tasks carried out by radiation workers are required to be completed safely to minimize and avoid altogether the occurrence of any accident and negative impact to the public and environment. Thus, the guidelines established under Act 304, whereas radiation workers must abide by OSHA 504 need to refer by the organization.⁴²

To increase public trust and positive perception, the preparation to establish an effective risk managing system is required.⁴³ Furthermore, the nuclear and radiation industry will also benefit from learning the practices of other industries having similar cultures in strengthening their safety practice approaches.⁴⁴

Safety Culture in Handling Low Dose Radioactive Material

Radiopharmaceuticals are one of the unique capabilities of nuclear medicine. It has its specialty and function. In addition, nuclear medical procedures are capable of mapping physiological function and metabolic activity also helps to provide specific information about organ function and dysfunction such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and Ultrasonography (US).⁴⁵

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A study in the radiopharmaceuticals production facility showed that the model offers interesting perspectives for the application of safety culture features in organizational management. A basis for the identification of potential problems in the radiopharmaceuticals package dispatch process has been provided in the leading indicator framework. Top-level commitment contributes the most feature of safety culture. These problems may be caused by the lack of flexibility and management organizations in which their use of financial resources to buy important pieces of equipment without complicated and time-consuming bidding processes. Thus, the perception of managers uncommitted to the safety culture of the production process as they should be done.

ALARA principle: shielding, distance and time
ALARA is defined as low as reasonably achievable. It is related to the work of exposing the radiation while maintaining the efficiency and reliability of the diagnostic modality.⁴⁶⁻⁵⁰ ALARA consists of three major principles which are time, distance and shielding. Time is important in which every second of the human body was exposed to the radiation is counted. Hence it is important to minimize the time of exposure. By limiting the time of exposure, will reduce the absorbed dose towards the body.

Next, increase the distance between the body and the source of radiation, this will help reduce the radiation by a factor of 4. The energy of the radiation can be stopped according to the type of energy it was. For instance, for x-rays and gamma rays it is very efficient to use lead as the shield to prevent the energy penetrate our body. There are lots of shielding types nowadays such as lead apron, lead glasses and lead barriers or blocks.

ALARA was first introduced during the Manhattan Project of World War II and the NCRP acknowledged the concept in 1954.⁵¹ By 1977, the ICRP presented the concept of ALARA as a philosophy of radiation protection based on quantifiable risks.⁵² According to the ALARA principle, all subjects related to radiation are associated with the principle whether how small the exposures may be. It is important to follow the principle to avoid other negative circumstances from happening. In the ALARA principle, both upper and lower boundaries are identified as 'action levels' and 'inaction levels'. This terminology has been used by ICRP for quite some time which is proposed by a group of NCRP.⁵³

ALARA principle is divided into two terms of action which is individual action level (IAL) and individual inaction level (IIL). These two terms explained about the dose limitation received in a population. For IAL, it is a level of individual exposure in which if it is exceeding the level will inevitably trigger a response in ALARA principle. It is suggested that the exposure must be reduced to a

reasonably achievable level without negotiating the uses of radiation and its benefits. In a general guideline, the IAL must be higher than the average dose but still not exceeding the standard level of limitation dose.⁵⁴

Meanwhile, the IIL is defined as the level of individual exposure below which no ALARA activity is required. Even though lower exposures could be reduced, it is not justified as it only has little effect upon the collective dose. Hence, the institution needs to monitor the limitation dose received and collected by all of its workers over a certain time. All the monitored data would be compiled and a collective action level (CAL) and a collective inaction level (CIL) can be established. It is based on the CAL and CIL the actions would be taken, if the CAL is exceeded then actions should be started to reduce the collective dose following the principle of ALARA, however, if the CIL is not exceeded, then no further action needed to be taken to reduce the collective dose.⁵⁴

Radiation is widely used in lots of medical instruments such as X-ray and computed tomography (CT). Since the use of paediatric computed tomography has increased for the past two decades, it has been stated that there is a small but significant increase of fatal cancer that may affect the lifetime of it.⁵⁵⁻⁵⁶ There is a study showing that this effect gives a significant impact on children. The ALARA principle may be implemented on the radiologists during conducting the procedure.

The first one is to develop weight-based protocols. He or she must have exposed the risks upon conducting the CT scan towards the children. This helps to increase awareness among the society. However, it is also important to reduce the dose while maintaining the efficiency of the CT scan.⁵⁷⁻⁵⁸

Next, the radiologists also could consider another alternative of non-radiation modality to evaluate the disease apart from using a CT scan. This is due to lower risks of being exposed to radiation. Other medical instruments could be used, for instance, ultrasound and magnetic resonance imaging (MRI). The ALARA principle could also be applied by improving the shielding along the exposed area. For example, a newly fabricated thyroid and breast shields can be used to reduce the impact.⁵⁹⁻⁶¹ Finally, it is also an ALARA principle to avoid repeating the CT studies. This is belonging to the time principle which reducing the time exposure towards the body.

Important of ALARA

The importance of ALARA is very crucial in the medical field especially in medical imaging such as CT scan which uses ionizing radiation as the source to conduct the procedures. In the UK it has been stated that medical diagnostic radiation exposures had caused 100 to 250 deaths every year.⁶² This is agreed by Brenner who mentioned that CT is an

increasing source of radiation dose.⁶³ This is due to the benefits of CT which did become life-saving in diagnosis and treatment planning and has been shown in which there is a sharp increase of CT exams from 1981 to 2006 from 2.8 to 6.2 million scans respectively.⁶⁴

However, if there is no precaution taken upon conducting the CT scans there will be more potential harms that could occur apart from the benefits. One of the phenomena that exist from this activity is "Radiophilia". It is defined as "unnecessary radiation exposure due to misunderstanding and underestimation of risk perception, risk conception and risk communication among healthcare employees involved in medical radiation imaging".⁶⁵

The previous study regarding Radiophilia has stated that numerous causes may lead to the phenomenon. The factors are related to tons of categories including physician, radiological technician, patient, equipment and economic issues. The most important factor is the lack of knowledge and awareness on radiation protection that emphasizes ALARA policy. When the policy is not being practiced, it leads to harmful effect as the Radiophilia.

Next, there are increasing numbers of careless clinicians that do not understand the importance of implementing the principle of ALARA whereas they tend to ask for repeating the CT because of their incorrect diagnosis or absence of physical examination. Whereas, by understanding the concept of ALARA this mistake could be avoided since ALARA discourages any repetition of the activity to lower the risk of exposure towards the patient and public.

There are few studies that show how well knowledge of ALARA has been understood and applied can help increase the awareness about radiation risks and be the first step to eliminate pointless radiation exposure. However, the studies show that inadequate procedures and radiological examinations had been carried out these past whiles.⁶⁶⁻⁶⁹ In 2012, a study has concluded that only minorities of physicians that were well informed regarding radiation protection awareness and this problem should be improved hastily.⁷⁰

Some other factors that contribute to Radiophilia which is a lack of attention to quality control of radiation units, image quality and patient dose assessment.⁷¹ ALARA is not enclosed to time, shielding and distance principles only but also in ensuring the physicians are well equipped with all information on handling and protecting the equipment, procedures and society on the risks of radiation exposure.

ALARA is very important to avoid any radiation-induced deterministic effects on the patients as well as medical staff during the ionizing radiation procedures that occurred.⁷²⁻⁷³ Some cases

have already been reported regarding this issue, for instance, there are two epidemiological studies that show that the children populations had gained positive feedbacks from radiation exposure received from CT scans and cancer incidence.⁷⁴ This is supported by a study that stated that the frequency of CT scans on children had increased three times for older children and two times for children under 5 years old these last 20 years.

Finally, three rules of radioprotection must be majorized by all healthcare employees to manage the radiation risks properly which are justification, optimization, and dose limitation. All sorts of training programs, education, nuclear physics classes and continuous assessment must be included during medicine to improve the understanding of radiation risks. Most importantly, there must be a collaborative effort among all medical staff and physicians to encourage the patients and public about the benefits, harmful effects and potential risks of the radiation exposure since the beginning of their treatments.

CONCLUSION

Promoting safety Culture in Handling Radioactive Material should be practiced and implemented in all aspects involving radioactive. Concept As Low As Reasonably Achievable can be applied to minimize radiation doses and releases of radioactive materials. Besides that, an effective ALARA program requires a commitment from all people, especially for radiation practitioners.

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